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Research Article

Language That Puts You in Touch With Your Bodily Feelings

The Multimodal Responsiveness of Affective Expressions

Francesco Foroni[1] and Gün R. Semin[2]

[1]Department of Social Psychology, VU University Amsterdam, and [2]Faculty of Social and Behavioral Sciences, University of Utrecht

ABSTRACT—*Observing and producing a smile activate the very same facial muscles. In Experiment 1, we predicted and found that verbal stimuli (action verbs) that refer to emotional expressions elicit the same facial muscle activity (facial electromyography) as visual stimuli do. These results are evidence that language referring to facial muscular activity is not amodal, as traditionally assumed, but is instead bodily grounded. These findings were extended in Experiment 2, in which subliminally presented verbal stimuli were shown to drive muscle activation and to shape judgments, but not when muscle activation was blocked. These experiments provide an important bridge between research on the neurobiological basis of language and related behavioral research. The implications of these findings for theories of language and other domains of cognitive psychology (e.g., priming) are discussed.*

It is well documented that perceiving a smile or a frown activates the corresponding facial muscles (e.g., Dimberg & Petterson, 2000; Dimberg, Thunberg, & Elmehed, 2000). Such mirroring in motor movements is assumed to guide people's understanding of other people in general (cf. Gallese, 2006; Rizzolatti & Craighero, 2004), as well as their understanding of their own and others' emotional states (Niedenthal, 2007). It is also assumed to influence emotional experience and to shape judgments (e.g., Ekman, Levenson, & Friesen, 1983; Winkielman, Niedenthal, & Oberman, 2008).

A question that arises in light of these findings is whether emotion language also induces motor resonance (e.g., Rüschemeyer, Lindemann, van Elk, & Bekkering, in press; Zwaan, in press; Zwaan & Taylor, 2006). In other words, when one reads or hears a word representing an emotional expression (e.g., *smile*), does that word recruit the neutral substrates and the muscles that are active when someone is performing that emotional expression (i.e., smiling)? Furthermore, does motor resonance mediate linguistic comprehension? An answer to these questions would contribute to researchers' understanding of how affective communication is grounded.

Such questions would not arise in the traditional view of language, according to which language is an amodal symbolic system (e.g., Fodor, 1983). However, recent research from an embodiment perspective (e.g., Barsalou, 2008; Glenberg, 2008; Semin & Smith, 2008) suggests that language comprehension involves simulation and recruitment of neural systems used for perception, action, and emotion (Buccino, Riggio, Melli, Gallese, & Rizzolatti, 2005; Hauk, Johnsrude, & Pulvermüller, 2004; Pulvermüller, 2005; Zwaan & Taylor, 2006). Neurophysiological conceptualizations of language understanding point to mental simulation processes driven by the mirror-neuron system (e.g., Fischer & Zwaan, 2008; Gallese & Lakoff, 2005; Rizzolatti & Arbib, 1998; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996; Rizzolatti, Fogassi, & Gallese, 2001; Tettamanti et al., 2005).

Findings from behavioral studies converge with this perspective. For instance, Havas, Glenberg, and Rinck (2007) covertly manipulated participants' expression of positive and negative emotions and showed that participants were quicker in judging sentence valence and sensibility when facial posture and sentence valence matched than when they mismatched. More recently, Niedenthal, Winkielman, Mondillon, and Vermeulen (2009) found that the conceptual processing of emotions involves somatic responses, as indicated by facial expressions of emotion, and that such responses are situated and context dependent.

Address correspondence to Francesco Foroni, VU University Amsterdam, FPP - Department of Social Psychology, Van der Boechorststraat 11081 BT Amsterdam, The Netherlands, e-mail: f.foroni@psy.vu.nl.

Psychological Science RESEARCH, THEORY, & APPLICATION IN PSYCHOLOGY AND RELATED SCIENCES

Notably, no experimental work has investigated whether *semantic* stimuli induce motor resonance in facial muscles comparable to that demonstrated in the case of facial expressions of emotion (e.g., Dimberg et al., 2000). Thus, the objective of the first experiment we report here was to investigate whether semantic stimuli induce such motor resonance. In addition, we attempted to specify the characteristics of the semantic stimuli that are likely to do so (i.e., verbs referring directly to facial expressions, such as *to smile*, vs. abstract representations of emotion-related states, such as *funny*).

The second experiment we report extrapolated from the first by examining whether subliminally presented semantic stimuli influence affective judgments by inducing motor resonance. This study relied on a paradigm developed by Strack, Martin, and Stepper (1988), which has revealed that mechanically activating smiling muscles (zygomatic major) influences judgments of how funny a cartoon is. Finding that subliminal semantic stimuli have the same effect would indicate that verbally induced motor resonance is used in the understanding of emotional states and emotional experience and also contributes to the shaping of judgments (as argued, e.g., by Ekman et al., 1983, and Winkielman et al., 2008).

EXPERIMENT 1

To investigate whether verbal stimuli referring to emotional expressions induce the same facial muscle activation in a reader or perceiver, and to achieve optimal comparability with the facial-mimicry literature, we focused on two specific facial expressions of emotion (i.e., smiling and frowning) and states associated with these expressions (i.e., happy and angry; see, e.g., Dimberg et al., 2000). We assessed motor resonance by means of electromyographic (EMG) measurement of the zygomatic major and corrugator supercilii muscle regions. For the verbal stimuli, we selected a set of action verbs that unambiguously map the perceptual features of the emotional expressions (e.g., *to smile*, *to frown*) and a set of adjectives (e.g., *funny*, *annoying*) that refer to the states associated with those expressions but do not have an unambiguous or direct reference to a specific expression. We expected that concrete verbs referring directly to facial expressions would induce motor resonance more strongly than adjectives expressing emotional states, because abstract emotion terms do not refer directly to specific behaviors or movements (e.g., Semin & Fiedler, 1988).

Method

Participants and Stimulus Material

Thirty students (23 females, 7 males; 26 right-handed, 4 left-handed; mean age = 21.2 years) volunteered to participate in this experiment for pay. The stimulus materials consisted of 12 Dutch words (6 verbs and 6 adjectives) related to positive and negative emotional expressions. (English translations in some cases are approximate, as no precise correspondence is available.) For positive emotional expressions, we used the verbs *to smile* (*glimlachen*), *to laugh* (*lachen*), and *to grin* (*grinniken*) and the adjectives *comical* (*komisch*), *funny* (*grappig*), and *entertaining* (*lollig*). For negative emotional expressions, we used the verbs *to frown* (*fronsen*), *to cry* (*huilen*), and *to squeal* (*janken*) and the adjectives *irritating* (*irritant*), *frustrating* (*frustrerend*), and *annoying* (*vervelend*). (Note that in Dutch, the infinitive form of verbs is clearly distinct from other forms.) In a pretest, participants rated each stimulus word on a 7-point scale ranging from *very negative* to *very positive*. The ratings were analyzed in a two-factor design with emotional expression (positive vs. negative) and linguistic category (action verb vs. adjective) as repeated measures variables. Positive emotion words ($M = 6.94$, $SD = 0.91$) were rated as more positive than negative emotion words ($M = 2.76$, $SD = 1.06$), $F(1, 14) = 96.78$, $p_{rep} = .99$. No other effect was significant.

Earlier research showed that distinct facial reactions to facial stimuli arise between 500 and 1,000 ms after stimulus onset (e.g., Dimberg et al., 2000). We expected critical effects to occur between 1,000 and 2,000 ms after stimulus onset because of the slower processing of verbal material (e.g., Snodgrass & McCullough, 1986).

Procedure, Apparatus, and Data Acquisition

The verbal stimuli were sequentially presented on a monitor in a soundproof experimental chamber. Each trial started with a fixation point (500 ms) that was followed by a baseline interval of 3 s and then the stimulus word for 6 s. The intertrial interval was 3 s. Participants received five blocks of words, each consisting of the 12 test words and 15 fillers. Facial muscle activity was measured using miniature Ag/AgCl electrodes attached on the left side of the face, over the zygomatic major and the corrugator supercilii muscle regions (Fridlund & Cacioppo, 1986). The skin was cleaned and prepared to reduce electrode-site impedance to less than 11 kV. The raw EMG activity was measured with a Neuroscan Synamps amplifier (Compumedics, El Paso, TX) at a sampling rate of 1000 Hz using two bipolar channels and a gain of 1,000. The digitized signal was filtered using a notch filter at 50 Hz and a band-pass filter from 10 to 200 Hz.

Data Preparation and Analyses

Phasic facial EMG responses (in microvolts) were scored and averaged over intervals of 250 ms during the first 2 s of stimulus presentation. The EMG responses were expressed as change in activity from the prestimulus level (i.e., 1,000 ms before stimulus onset). Separate analyses of variance were performed for the zygomatic and corrugator muscle regions. As suggested by other researchers (e.g., Dimberg, Thunberg, & Grunedal, 2002; Kirk, 1968), we used Geisser-Greenhouse conservative F tests to reduce the likelihood of positively biased tests. A priori comparisons between means (e.g., verbs vs. adjectives) were evaluated by t tests.

The data were analyzed in a three-factor design with emotional expression (positive vs. negative), linguistic category (action verb vs. adjective), and period (eight intervals of 250 ms each) as repeated measure variables.

Results

Zygomatic Major Muscle

Figure 1 shows the results for the zygomatic major muscle. Our main hypothesis was confirmed by the significant three-way interaction of linguistic category, emotional expression, and period, $F(3, 97) = 2.78$, $p_{\text{rep}} = .93$, $\eta_p^2 = .09$. Participants showed a significant increase in activation of the zygomatic major muscle when presented with words related to positive emotion. However, this effect was qualified by linguistic category: Activation was significantly stronger for action verbs (e.g., *to smile*) than for adjectives (e.g., *funny*) after 1,000 ms, all p_{rep}s $> .92$. This result was paralleled by the larger inhibition produced by action verbs than by adjectives for the negative emotional expressions. The negative verbs produced a significant inhibition of the zygomatic major (after 1,000 ms, all p_{rep}s $>$ .88), whereas the negative adjectives did not. In general, zygomatic major EMG activity increased over time, $F(2, 45) = 4.26$, $p_{\text{rep}} = .94$, $\eta_p^2 = .13$, and was larger for positive words than for negative words, $F(1, 29) = 4.09$, $p_{\text{rep}} = .91$, $\eta_p^2 = .12$. The significant Emotional Expression × Period interaction, $F(1, 38) = 4.75$, $p_{\text{rep}} = .94$, $\eta_p^2 = .14$, reflected the fact that negative words were not associated with an increase in EMG activity over time, whereas positive words were associated with a significant increase.

Corrugator Supercilii Muscle

Figure 2 shows the results for the corrugator supercilii muscle and reveals the expected pattern. Our main hypothesis was again confirmed by the significant three-way interaction of linguistic category, emotional expression, and period, $F(4, 116) = 2.38$, $p_{\text{rep}} = .91$, $\eta_p^2 = .08$. Participants registered a larger activation of the corrugator supercilii when presented with negative verbs than when presented with negative adjectives and with positive verbs and adjectives. They showed a significant inhibition of the corrugator supercilii muscle when presented with both positive action verbs (after 500 ms, all p_{rep}s $>$ .91) and positive adjectives (after 500 ms, except at 1,750 ms, all p_{rep}s $> .92$). Overall, EMG activity changed significantly over time, $F(2, 49) = 4.93$, $p_{\text{rep}} = .96$, $\eta_p^2 = .14$. Moreover, positive words, in general, yielded a larger inhibition than negative words, $F(1, 29) = 4.37$, $p_{\text{rep}} = .92$, $\eta_p^2 = .13$. Response to negative words did not change over time, whereas positive words inhibited the corrugator supercilii progressively over time, as revealed by the Emotional Expression × Period interaction, $F(3, 81) = 2.92$, $p_{\text{rep}} = .92$, $\eta_p^2 = .09$.

Discussion

The results clearly demonstrate motor resonance to unambiguous verbal expressions of emotion (action verbs: e.g., *to smile*, *to frown*); the corresponding muscles (i.e., zygomatic major and corrugator supercilii) were recruited after participants read these words. Such motor resonance was also observed for abstract terms (adjectives representing corresponding emotional states). In this case, however, the resonance was usually sig-

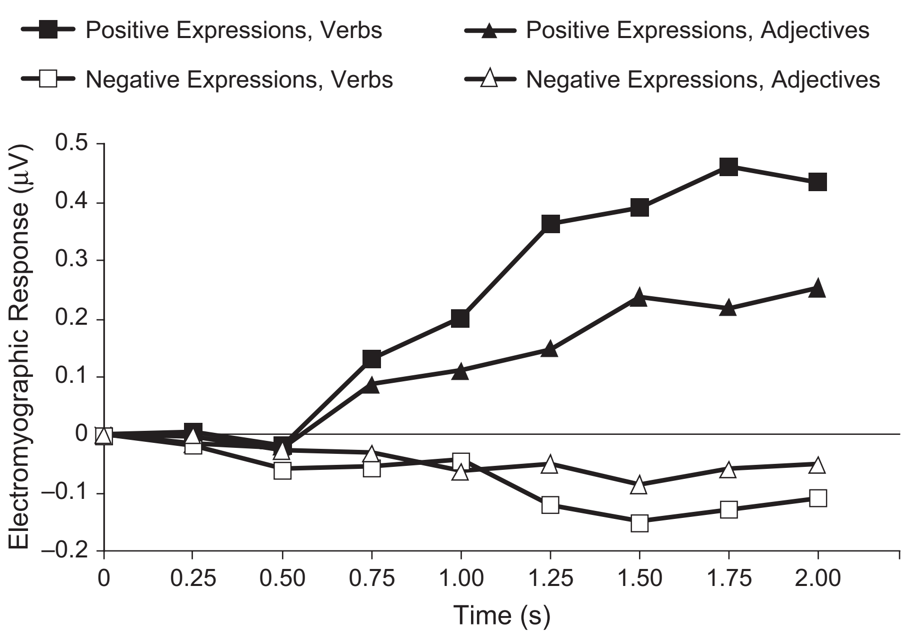

Fig. 1. Results from Experiment 1: mean facial electromyographic response for the zygomatic major muscle region, plotted in intervals of 250 ms, during the first 2 s of exposure to the verbal stimulus. Results are shown separately for each combination of linguistic category and emotional expression.

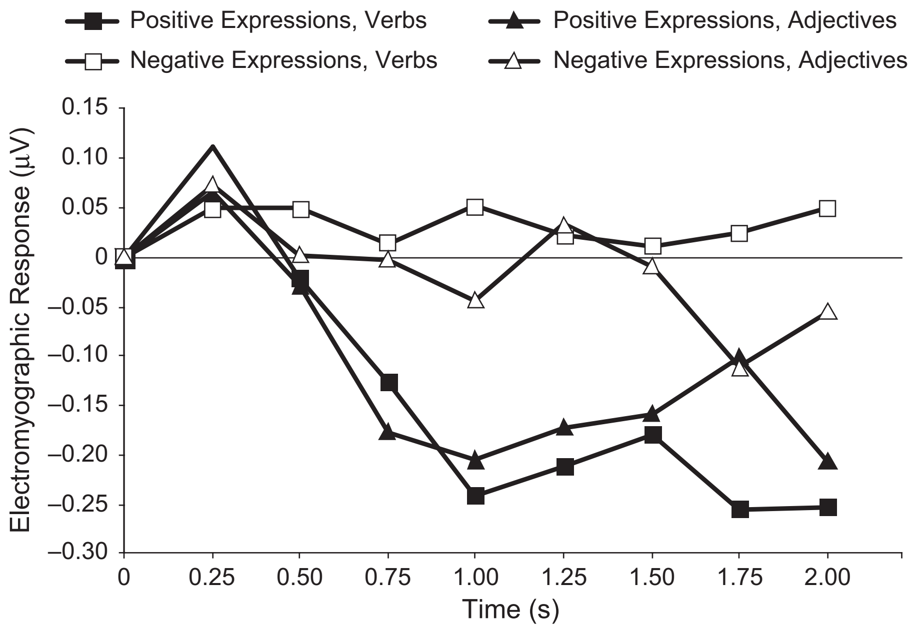

Fig. 2. Results from Experiment 1: mean facial electromyographic response for the corrugator supercilii muscle region, plotted in intervals of 250 ms, during the first 2 s of exposure to the verbal stimulus. Results are shown separately for each combination of linguistic category and emotional expression.

nificantly weaker in intensity. This pattern of results parallels nearly perfectly those reported when facial expressions were the stimuli (e.g., Dimberg & Petterson, 2000; Dimberg et al., 2000). The findings provide unequivocal evidence for the suggested commensurability of linguistic and visual stimuli. These results also demonstrate that verbal stimuli referring to emotional expressions are embodied. Furthermore, they suggest that the communicative potency of language is not merely symbolic, but also somatic.

EXPERIMENT 2

Experiment 2 was designed to extend the findings of the first experiment by examining the impact of subliminally presented verbal stimuli on social judgments and the role that motor resonance may play in this process. To this end, participants were presented subliminally with verbal stimuli (verbs vs. adjectives) and asked to rate how funny a series of cartoons were. For some participants, motor resonance was inhibited (i.e., participants held a pen with their lips; see Strack et al., 1988). We predicted that in the uninhibited condition, motor resonance would be a function of the linguistic category. The results of Experiment 1 suggest that if motor resonance is responsible for shaping affective judgments (e.g., Strack et al., 1988), verbs referring to positive expressions (e.g., *to smile*) would enhance funniness ratings, whereas verbs representing negative expressions (e.g., *to frown*) would depress these ratings. We did not expect the same result for adjectives, which had been shown to induce weaker motor resonance. Moreover, if language is embodied, then these effects would be nullified when the relevant muscles were inhibited.

Method

One hundred sixty-four students (105 females, 59 males; mean age = 20.7 years) volunteered to participate in this experiment for pay. In addition to the 12 stimulus words from Experiment 1, the stimulus materials included 24 cartoons selected on the basis of a pretest. In the pretest, the cartoons were rated for funniness by an independent sample. We selected 24 cartoons that on average were around the midpoint of the funniness scale ($M = 5.75$, $SD = 0.18$).

Each trial started with a fixation point. After a variable interval (500–1,500 ms), a stimulus word was presented for 30 ms, preceded and followed by a 30-ms mask consisting of a string of *X*s. Participants were instructed to press the space bar as soon as they saw a flash (i.e., mask). Postexperimental debriefing determined that participants were unaware that words were subliminally presented. A cartoon was presented after each masked word and stayed on the screen until the participant read the caption and rated how funny the cartoon was (on a 9-point scale from *not at all funny* to *extremely funny*). There were 24 trials. Each trial consisted of one verbal stimulus and one cartoon, randomly combined for each participant.

Each participant was randomly assigned to one of eight between-participants conditions of the $2 \times 2 \times 2$ design: Linguistic Category (action verb vs. adjective) × Emotional Expression (positive vs. negative) × Muscle Condition (no in-

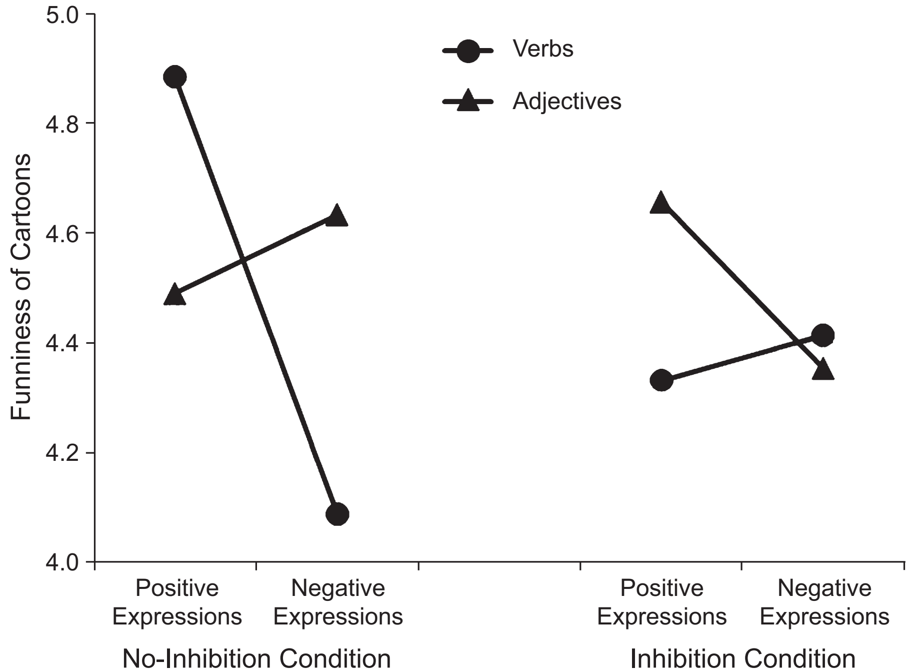

Fig. 3. Results from Experiment 2: mean funniness rating as a function of linguistic category, emotional expression, and muscle condition.

hibition vs. inhibition). Participants in the inhibition condition held a pen between their lips. This position is known to inhibit facial muscle activity and to preclude muscle resonance (e.g., Niedenthal, 2007).

Results

Funniness ratings were aggregated for each participant to yield a funniness score.[1] These ratings are presented in Figure 3. The predicted three-way interaction of linguistic category, emotional expression, and muscle condition was significant, $F(1, 156) = 4.31$, $p_{rep} = .92$, $\eta_p^2 = .03$. Participants in the no-inhibition condition showed the expected two-way interaction between linguistic category and emotional expression, $F(1, 74) = 4.49$, $p_{rep} = .93$, $\eta_p^2 = .06$. Participants' judgments after positive adjectives ($M = 4.49$, $SD = 0.94$) and after negative adjectives ($M = 4.63$, $SD = 1.13$) did not differ significantly, $t < 1$. In contrast, as hypothesized, participants in the positive-verbs condition rated the cartoons significantly funnier ($M = 4.88$, $SD = 0.80$) than participants in the negative-verbs condition ($M = 4.09$, $SD = 1.00$), $t(35) = 2.69$, $p_{rep} = .96$, $\eta_p^2 = .88$. Also as expected, when participants' motor resonance was inhibited, the two-way interaction was not significant ($F < 1$), and neither were the other comparisons (ts < 1).

[1]To ensure that our analysis included only those trials on which participants appeared to perform the priming task correctly, we excluded ratings from trials on which the reaction time (RT) on the simple RT task was too slow (RTs > 1,600 ms; 11.7% of all trials); such slow RTs indicate that the participant did not attend to the prime. Analyses including those trials yielded a similar pattern of results, but with slightly reduced statistical power.

Discussion

The second experiment revealed that even when verbal stimuli are presented subliminally, they influence affective ratings. Notably, and as predicted, this effect was obtained only when there was a potential for motor resonance, and not when this possibility was blocked. This particular comparison between the inhibition (pen) and no-inhibition (no-pen) conditions further highlights how motor resonance induced by verbal stimuli contributes to judgments.

Moreover, the type of verbal stimulus appears to influence judgments. Motor resonance is present for verbs referring to emotional expressions, and to some extent for adjectives referring to emotional states. The intensity difference in motor resonance found in Experiment 1 appears to be reflected in the differential effect of verbal stimuli on judgments (verbs show an effect, whereas adjectives do not). It could be argued that motor resonance has to reach a certain threshold in order to have an impact on judgments.

This pattern of data cannot be explained by a simple evaluative difference between positive and negative emotional words (i.e., affective priming). Within each emotional category, the verbs and adjectives were matched in valence (see Experiment 1). Thus, the differential effects of the two linguistic categories (verbs vs. adjectives) in the no-inhibition condition and the lack of any effects in the inhibition condition cannot be accounted for by simple evaluative priming.

GENERAL DISCUSSION

The studies reported here were designed to cast the linguistic representation of specific affective expressions into a socially embodied framework. To this end, we built on earlier research showing (a) that observing a smile (or frown) induces a smile (or frown) response (e.g., Dimberg & Petterson, 2000; Dimberg et al., 2000) and (b) that a mechanically induced smile influences evaluative judgments (Strack et al., 1988) via proprioceptive feedback.

We have shown that exposure to verbs referring unambiguously to emotional expressions induces motor resonance comparable to that induced by exposure to facial expressions (e.g., Dimberg et al., 2000). Motor resonance is also induced, to a lesser degree, by exposure to more abstract verbal stimuli representing emotional states. In addition, we have shown that the subliminal presentation of verbs referring to facial expressions of positive and negative emotion shapes readers' evaluation of cartoons. Adjectives did not have the same effect. Finally, the differential pattern of judgments was not found when participants' facial muscle movement was blocked. These results have a number of implications.

One of the implications relates to recent work in neuroscience that has furnished new insights about the neural mapping of language, and action verbs in particular (Pulvermüller, 2005). In a recent functional magnetic resonance imaging (fMRI) study, Hauk et al. (2004) showed that listening to verbs referring to leg actions activates regions of the motor cortex responsible for control of the leg; in the case of verbs referring to hand actions, motor cortex regions responsible for hand control are activated, and so on. Using fMRI, Tettamanti et al. (2005) demonstrated somatotopic representation of actions described by simple sentences (e.g., "I kick the ball"). Although the fMRI research constitutes a fascinating illustration of the neural grounding of action verbs, the data remain ambiguous: They might reflect simulation of action after hearing action verbs (i.e., an association), or they might instead indicate that activity in motor areas of the brain is important for understanding these verbs. Although recent research by Buccino and his colleagues (2005) suggests a strong connection between action and language that originates in the brain and extends to the periphery of the body, the evidence we have presented provides a clear resolution to issues left open by earlier research.

Our findings that action verbs give rise to the same motor resonance demonstrated earlier for faces complement the neuroscientific findings just noted, but they also show that such resonance contributes to affective judgments. The two experiments presented here provide a clear embodied grounding of emotional language and thereby constitute an important bridge among the fields of social cognition and affective processes (e.g., Strack et al., 1988), psychophysiological work on mimicry (e.g., Dimberg et al., 2000), and neuroscientific work on language (e.g., Pulvermüller, 2005). Our findings are clearly in line with the indexical hypothesis of language comprehension (Glenberg & Robertson, 1999, 2000), according to which language comprehension (e.g., understanding the verb *to smile*) leads to physical simulation of the events to be comprehended. In fact, this hypothesis posits that such simulation is necessary for comprehension. We have shown that such simulation occurs during language comprehension and, further, that it shapes people's judgments.

Finally, the differential results obtained using the two linguistic categories (verbs that refer to muscle activity and abstract adjectives) speak to other central research fields. For example, our findings provide a novel perspective on affective priming (e.g., Musch & Klauer, 2003). In the extensive research in this area, stimulus material has been carefully controlled for valence and semantic and other features (e.g., word length, frequency of occurrence). However, researchers have not attended to the distinctions among different categories of linguistic expressions. As we have shown, not all linguistic expressions have the same consequences. Certain categories induce motor resonance more than others and contribute differentially to the shaping of judgments. The implications of our findings for affective priming in particular and priming research in general are considerable. It appears that factors aside from valence and affective loading influence judgments. That is, words may influence judgments via motor resonance (when it reaches a certain threshold), and do not necessarily influence judgments through their positivity or negativity.

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